A photograph of the Space Shuttle Columbia on the Mobile Launcher Platform being moved by the Crawler-Transporter at night. The shuttle is white with a yellow nose cone and is being transported on a large, multi-level metal structure. The background is a dark blue sky with some clouds. The text "Restoration of the Shuttle Mission Simulator 'Motion Base'" is overlaid in white.

Restoration of the Shuttle Mission Simulator “Motion Base”

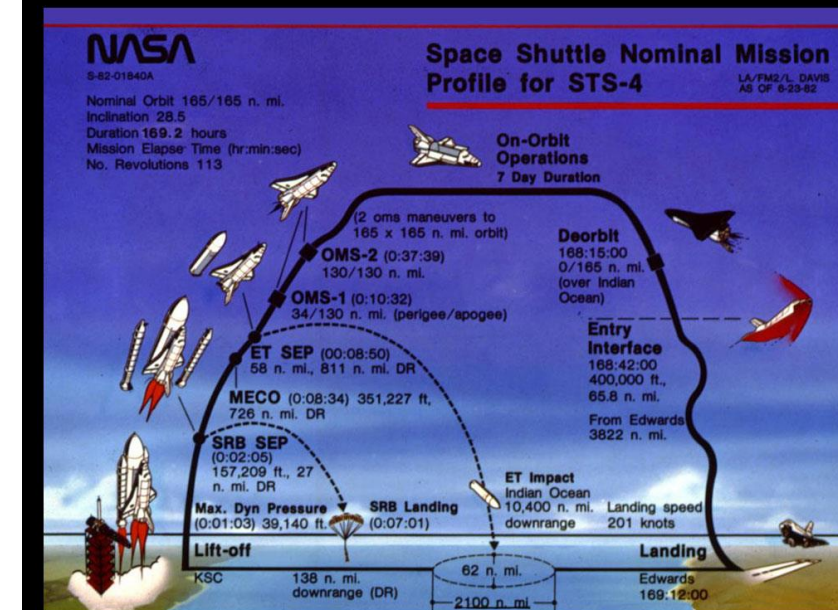
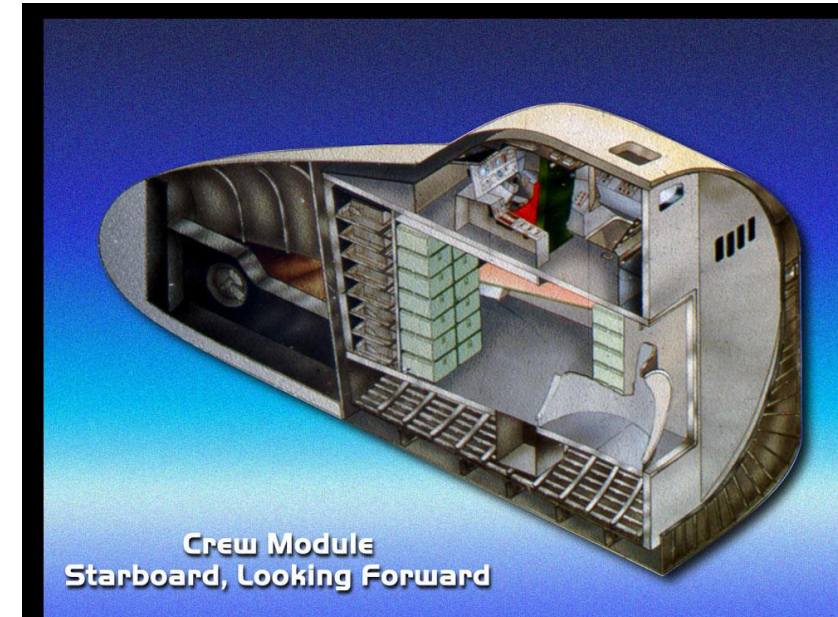
Carl Brainerd

Team Lead, Motion Base Restoration

11/14/21

What Was the Shuttle Mission Simulator (SMS), Anyway?

- The SMS consisted of full-fidelity, fully-functional Space Shuttle flight deck replicas (i.e. flight simulators) used to train Space Shuttle crews and mission controllers



• The SMS complex in JSC Buildings 5 and 35 consisted of-

- Two complete flight deck simulators that did not move (“**Fixed Base**”)
 - Complete forward and aft flight decks plus partial Mid-Deck and functional galley
 - All windows active
 - Focused mostly on orbit operations
 - Accessed in a realistic way- climbing through a hatch in the floor
- One simulator mounted on a hydraulic motion platform, i.e. the “**Motion Base**”
 - Forward flight deck only due to mechanical and access constraints
 - Focused on dynamic flight phases- ascent and entry
 - Had the unusual capability of rotating the nose up nearly 90 deg for more realistic ascent simulation
- Connection to the Mission Control Center via a network simulation

Other SMS Background

- Originally built in mid-1970s by the **Link** flight simulator company
- Contained a full complement of actual flight computers running the actual flight software
- Computer-generated out-the-window views
- High-fidelity simulation of Shuttle systems, as necessary to make it look real at MCC
- Thousands of simulated malfunctions programmed in the software
- A “roomful of computers” to make it all work.

Simulator Relocation when Space Shuttle Retired

- After the last Shuttle flight, the complex was disassembled (2011-2012)-
 - One Fixed Base went to Adler Planetarium (Chicago), now at Stafford Air & Space museum in Oklahoma
 - One Fixed Base went to Wings of Dreams Aviation Museum (Florida), now at Pima Air & Space Museum in Tucson, AZ
 - ***Motion Base “bought” by Texas A&M University (TAMU)/Texas Engineering Experiment Station (TEES) for \$500,000, and will be donated to the Lone Star Flight Museum (LSFM) upon completion of the restoration. (NASA Value > \$2M)***



Motion Base Simulator

- Cab mounted on motion system, including the pitch-up feature



Inside View of an SMS Crew Station



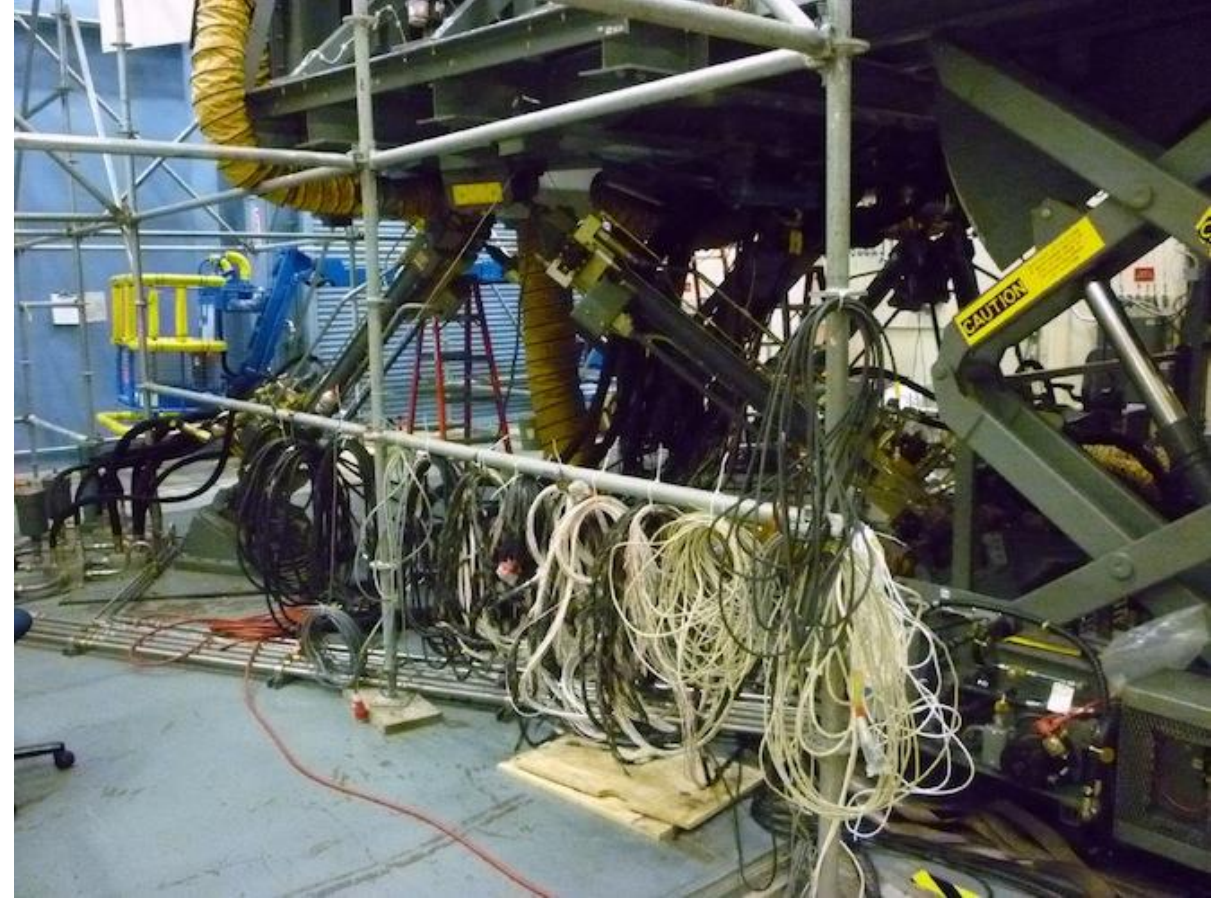
Our Goal- Make it look like this again!

Motion Base Disassembly Took Place in 2011-2012

The last flight of any SMS base, on October 11, 2011 (on Motion Base)



Motion Base (MB) Disassembly- Cables



Disassembly- Inside Crew Station



Disassembly- Mechanical

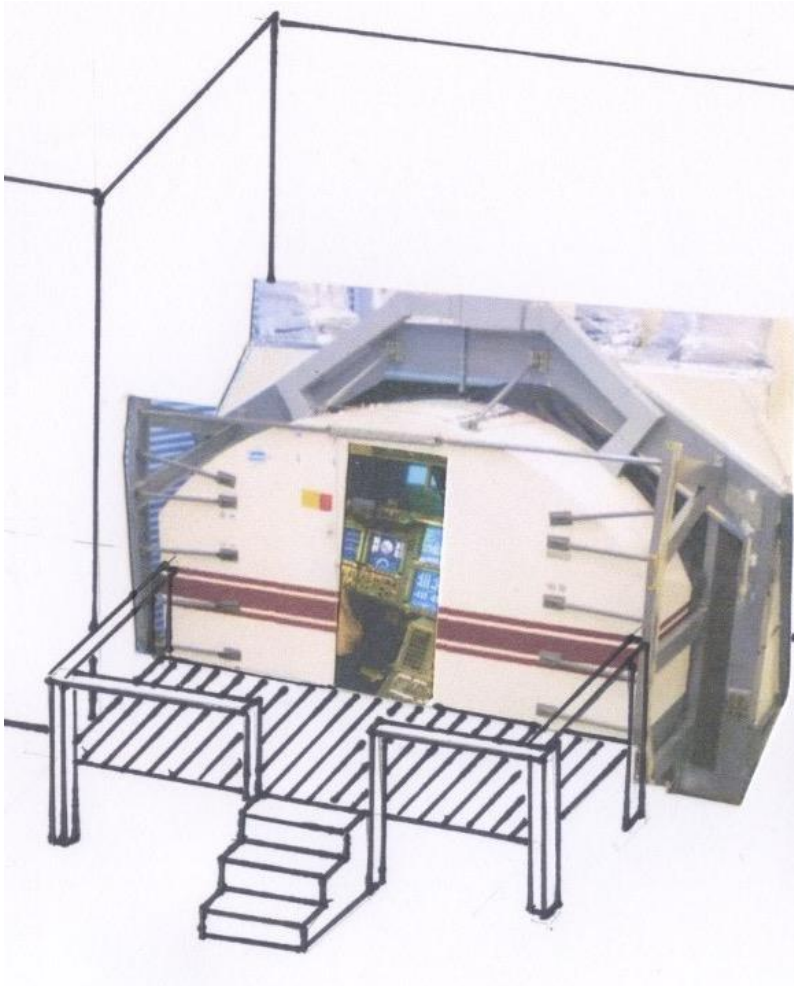


Fast-Forwarding to Today

- TAMU intended to reassemble the entire simulator on campus but was not able to do it because the planned space was re-allocated by the University
- MB was put into storage from 2012 until early 2021
- In the meantime, Houston had no Shuttle artifacts other than the 747 at Space Center Houston
 - This needed fixing!
- In 2016, TAMU “ITAR ownership” of the MB was transferred to Professor Bonnie J. Dunbar (retired astronaut) in the Aerospace Engineering Dept ---she was tasked by the College of Engineering with finding it a new home.
- In 2016, I contacted Bonnie about helping get the MB on display somewhere, preferably in Houston
- Dr. Dunbar pitched it to the LSFM Board of Trustees in December, 2016, however, it was before they moved the Museum from Galveston Field to Ellington and before the new building was even started. No commitment was received at that time.
- In 2017 I prepared a White Paper on possible display options as information for any interested party.
- In December, 2020, Dr. Dunbar again presented the proposal to the full Board of Trustees of LSFM and they agreed to accept and display the MB in the new LSFM at Ellington if fully restored.
- In December, 2020, NASA JSC Director Mark Geyer agreed to house the restoration on site in Bldg49 if the minimum restoration funds were raised.
- A fundraising campaign was initiated by Dr. Dunbar, Mr. George Abbey and Mr. Gerry Griffin, with threshold funds raised to meet JSC and LSFM requirements—thank you to all the donors
- Plans then started to coalesce for relocation, reassembly, and restoration of the MB simulator
- The MB move from College Station to NASA JSC occurred on June 1-3, 2021

Display Concept for LSFM

- Display concept includes the cab, an access platform, 1-2 display cases, and one audio/video console



Display Concept for LSFM

- Everything will be on wheels
- Computer complex will not be included due to space constraints
- Static display of the Crew Station cab without the motion hardware
- Cab will have lighting activated and representative hard copies of crew displays in place
- A former instructor console will be used for audio/video display of training sessions and other TBD material
- Recordings of crew training sessions are available and will be shown on a monitor in the cab and at the console (crew displays and out-the-window view, with sound)-
Demonstration to follow.
- Display cases will display small artifacts (Flight Data File, comm gear, COAS, flight laptops, etc.)
- Appropriate signage will be generated
- An access platform will be built to mate with the cockpit door.

Getting Started on Restoration

- TAMU funded all MB transportation/moving from College Station to NASA JSC
- Working space was arranged through the JSC Center Director's office (Building 49)
- Extensive reviews of property listings were done to determine what to ship and what to dispose
- A diverse restoration team was recruited, including
 - Former simulator engineers
 - Former simulator maintenance technicians
 - Former crew training instructors
 - Other Shuttle program technical personnel
 - Former simulator project manager
- The required MB equipment was packed up and shipped from TAMU to JSC

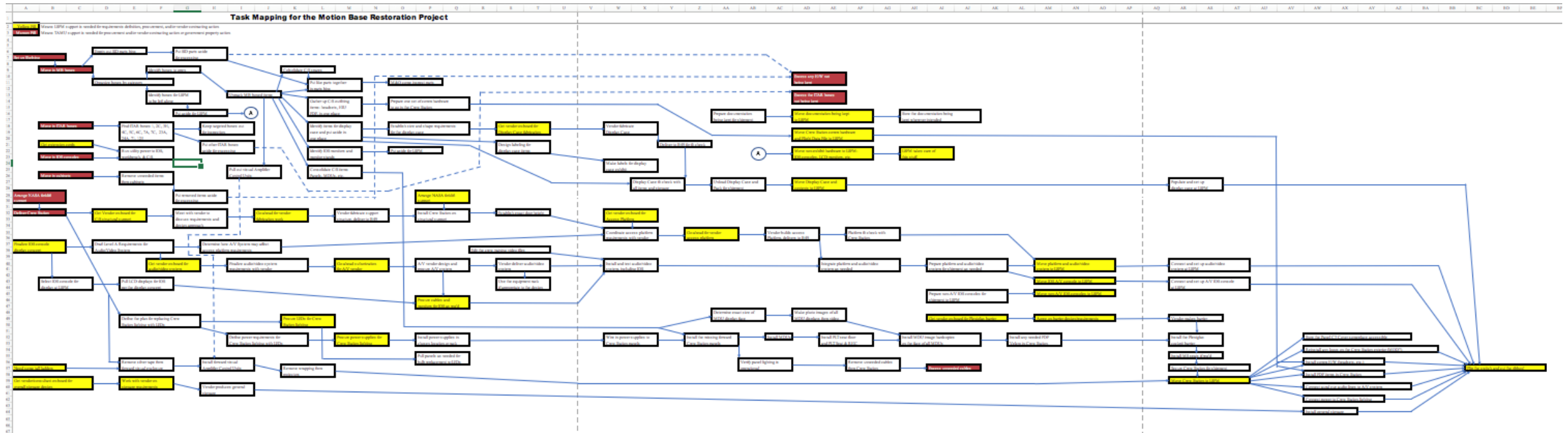
MB at TAMU before Shipping



MB Arrived at JSC on 6/1 (250 boxes) & 6/3 (Cab)



- A task-based project plan was made-



Tasks to be Done (Page 1 of 4)

- Inspect ~250 boxes of parts and documentation to determine what to keep
- Organize and inspect parts needed for the final display
 - Identify parts for Crew Station outfitting (comm gear, kneeboards, pencils, etc.)
 - Identify Flight Data File items for Crew Station (checklists, cue cards)
 - Identify and isolate items for the display case
 - Verify all needed hardware is accounted for-
 - Switch panels
 - Hand Controllers
 - Seats
 - Cockpit Display Units
- Get tools and supplies, ladders, extension cords, lights, fans, etc.
- Run power to the workbenches (former instructor consoles)
- Activate AC power at the Crew Station utility power outlets
- Replace all incandescent lighting with LEDs (not as easy as it sounds, more on this later)

Tasks to be Done (Page 2 of 4)

- Get a new wheeled “cradle” under the Crew Station
- Remove unneeded cables from inside and under the Crew Station
- Prepare an electronics cabinet to control the power to the display and to house a video player and power supplies
- Procure and install new power supplies for the lighting circuits (5 VDC, 12 VDC, 28 VDC)
- Procure a new audio amplifier and Blu-ray player for the crew station audio/video
- Remove silver “duct tape” from all joints on the exterior and clean up the mess
- Polish the rust off the switch guards on the switch panels
- Select, procure, and install casters under the instructor consoles (did not previously have wheels)
- Edit training session videos into museum-quality videos
- Select a point in time to configure the Crew Station for (We selected ~80K ft altitude on entry)
 - Determine switch settings
 - Determine talkback indications
 - Determine PBI indications

Tasks to be Done (Page 3 of 4)

- Design and implement new wiring for the Crew Station lighting and indicators, with the new power supplies
 - Switch panel overlays (5 VDC)
 - Push-button indicators- PBIs (5 VDC)
 - Glareshield floodlights (12 VDC)
 - Crew Station floodlights (28 VDC)
 - Talkback indicators (28 VDC)
 - Meter illumination (5 VDC)
- Remove forward enclosure closeout panels, get them painted, and reinstall
- Reinstall visual projector amplifier boxes around the forward enclosure
- Reinstall Crew Station panels and hook up the lighting power
- Make photo hardcopies of cockpit displays from the training videos (to be placed on face of the displays)

Tasks to be Done (Page 4 of 4)

- Reinstall cockpit displays
- Reinstall the pilot seat and hand controller
- Make an access platform/stairway
- Make a display case and populate it
- Make appropriate signage for the display
- Procure a TV monitor for the Crew Station video display, install and hook it up
- Define concept for audio/video display at the console
 - Make audio/video content as needed
 - Procure TV monitor and other electronics as needed
 - Install the equipment
- Get the cab exterior and cockpit floor painted (scheduled Jan, 2022 at EFD)
- When ready, move everything to LSFM, install it, and "flip the switch"

Project photos follow.....

Project Working Space Overview



Working on the Power Cables



Cleaning Off the Duct Tape Sealing the Joints



Removing Cables from Overhead Panels



Cables Being Removed from Crew Station



Overhead Floodlight On, Wirebrushing Switchguards



Items Gathered Up for the Display Case (partial)

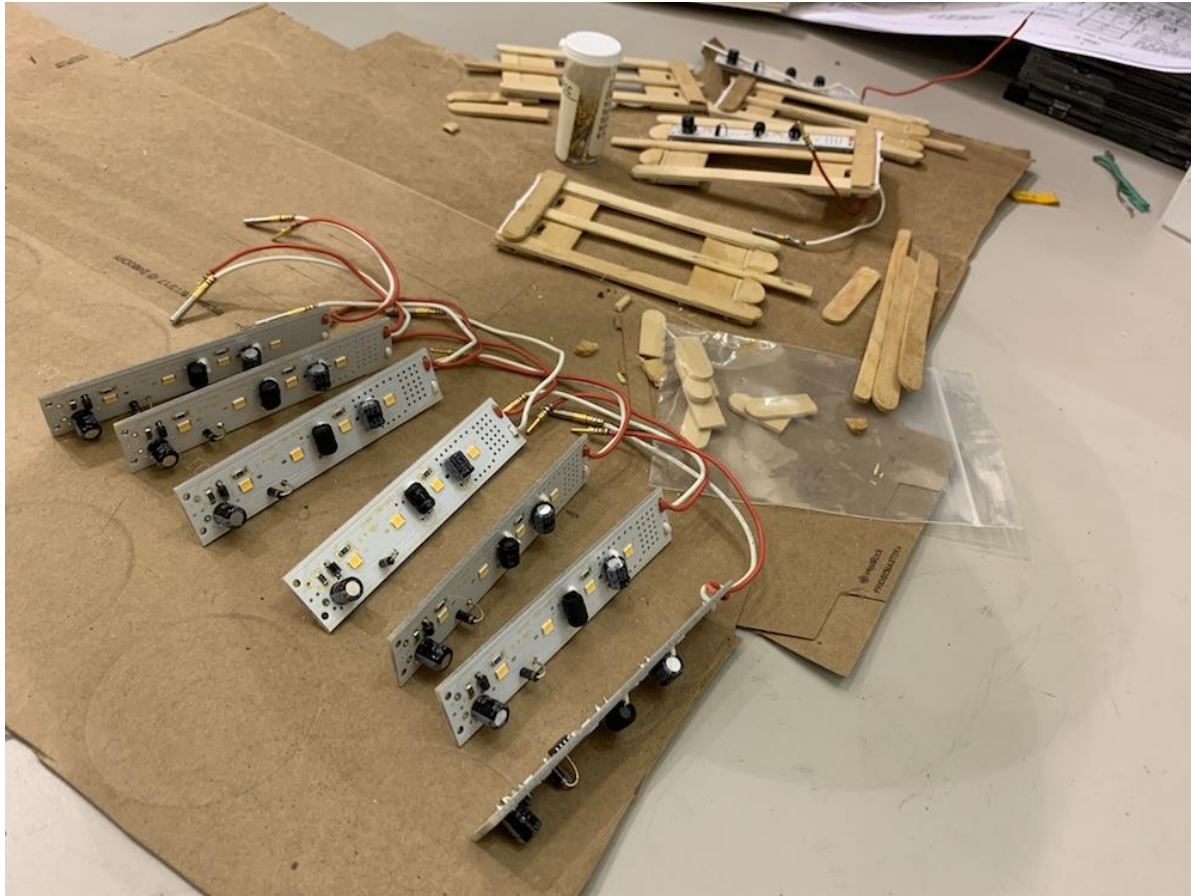


Working on Panel Wiring and the Power Cabinet



Glareshield Floodlight LED Lighting

- Not a “plug-n-play” installation
- Used parts from an RV LED fixture, fit into a newly-built jig



Glareshield Floodlight Bench Test

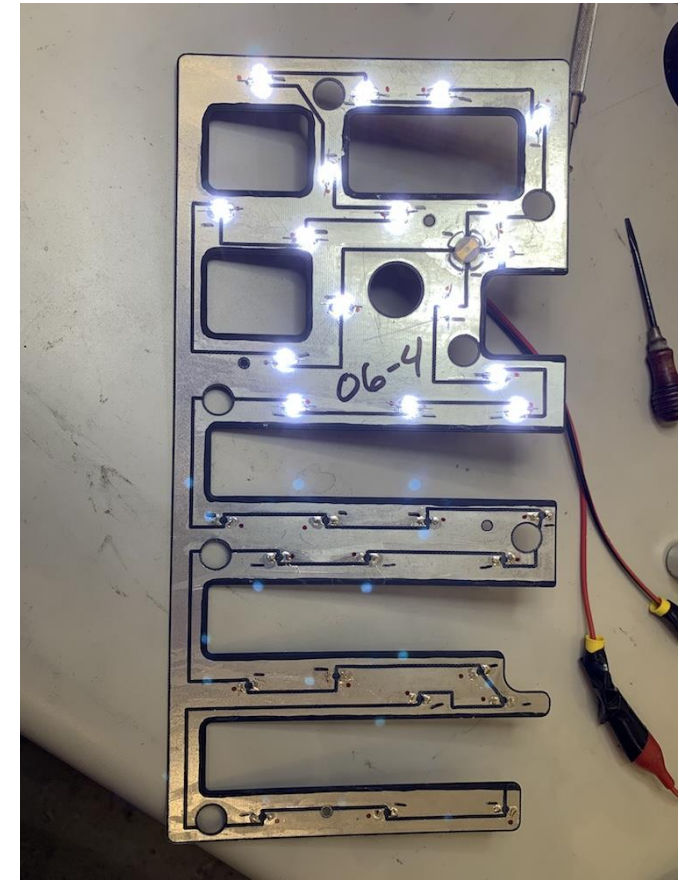


Putting LED Lighting into the Meters

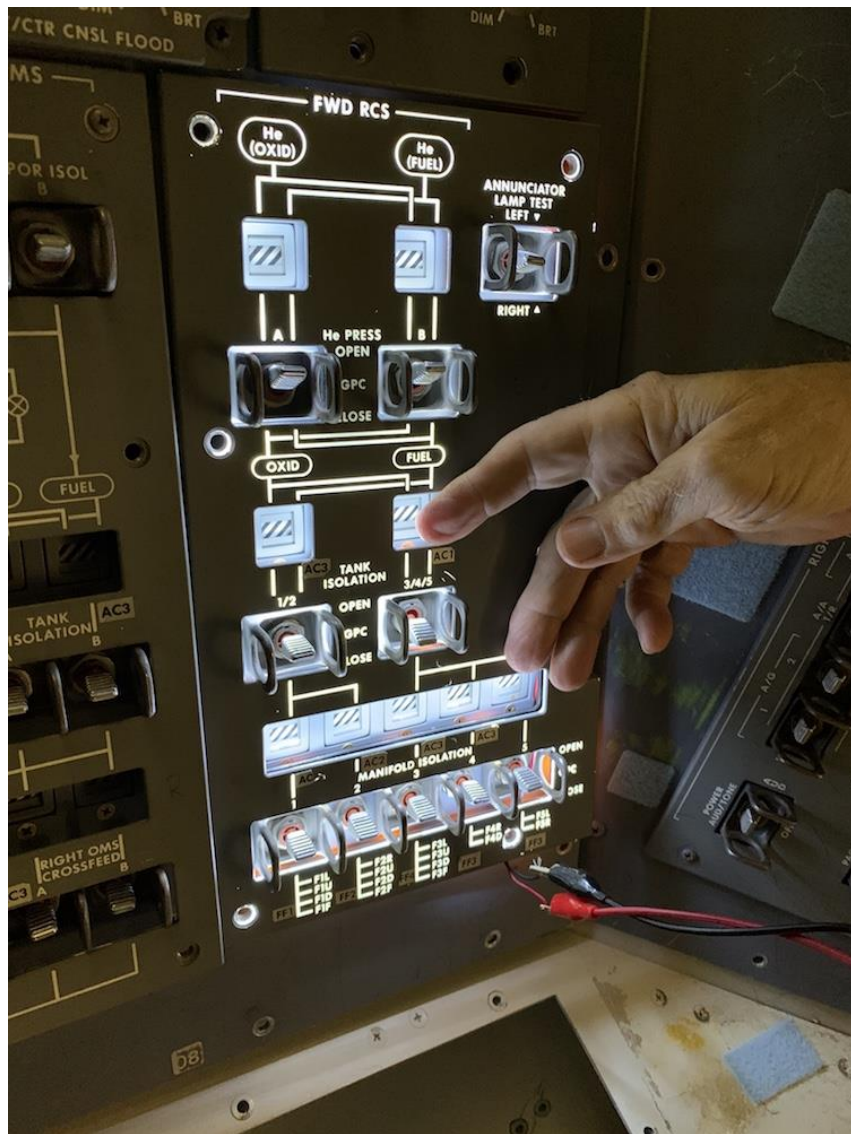


Panel Illumination LED Conversion was Complex

- Old system used 1600 tiny incandescent bulbs soldered onto circuit boards
- Space was tight, so finding the right LED solution was critical
- LED conversion required unsoldering the 1600 bulbs and soldering 1600 LEDs in their place



First Panels Converted to LED



New Blu-ray Player and Audio Amp

- Will provide video and audio to the Crew Station (STS-135 training session recordings)



Frame Grab of Training Video (sample to be Shown)



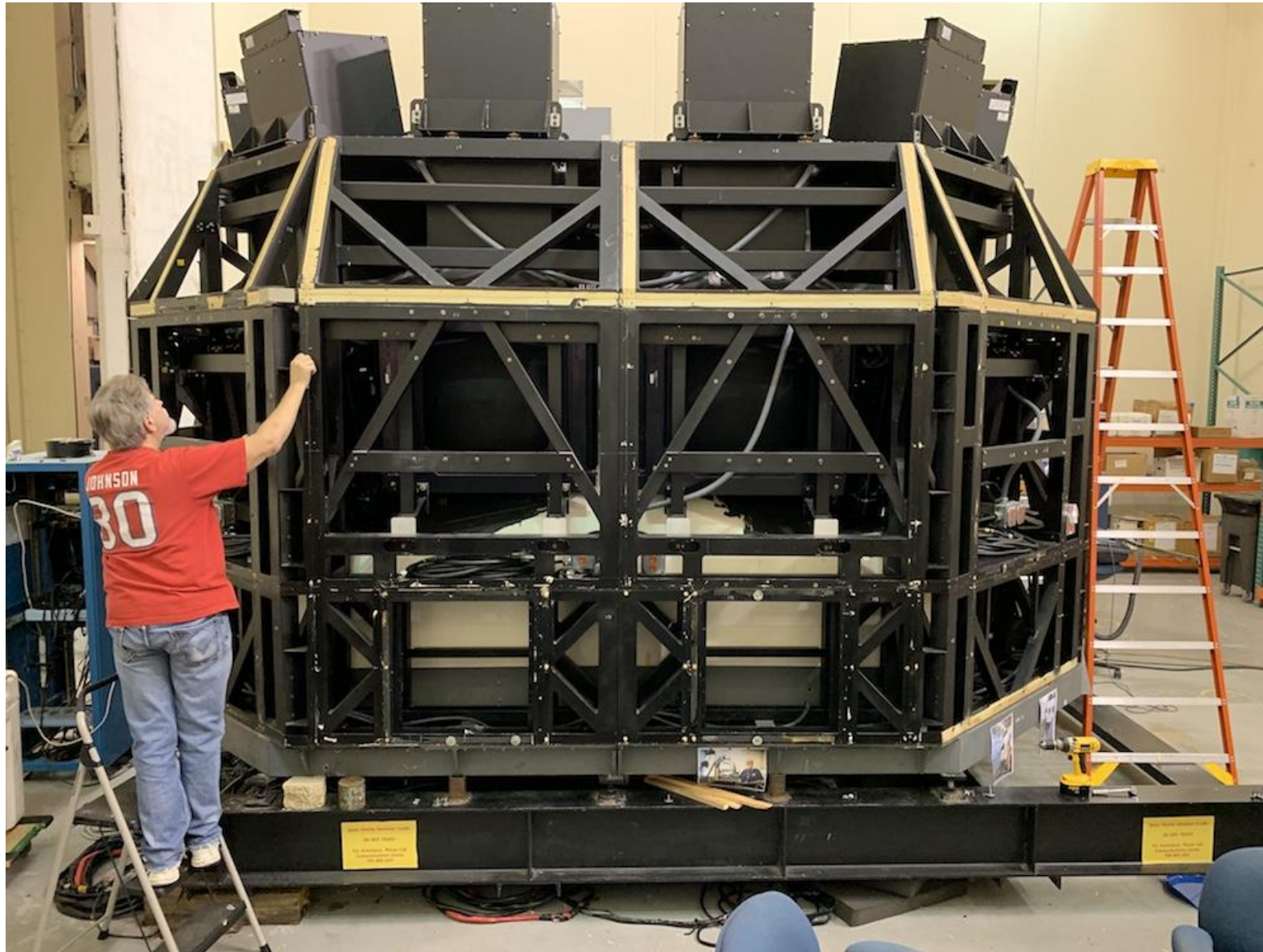
Simulated Displays (Hardcopy from Videos)



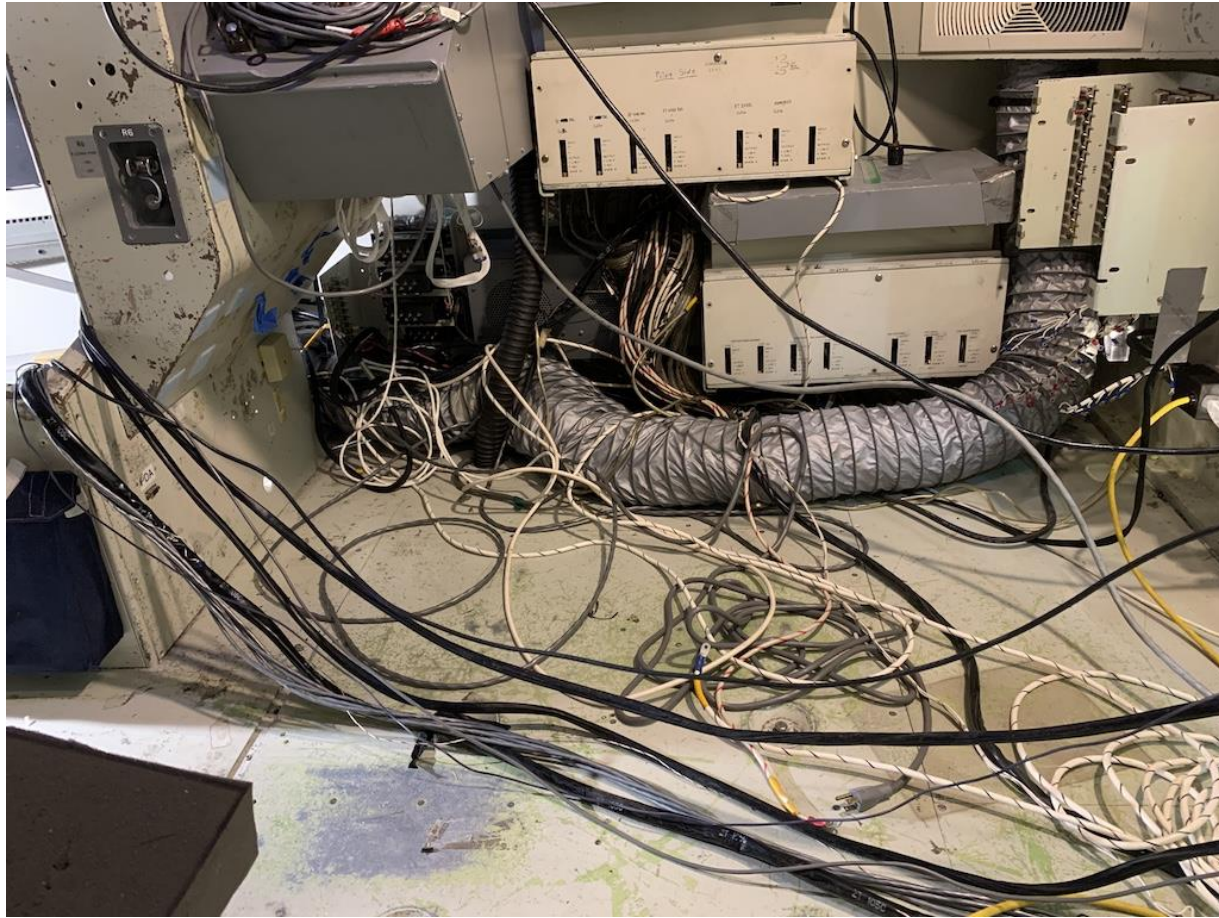
Caster Installation on Instructor Consoles



Enclosure Panels Removed for Painting



Cleaning Up the Aft Cockpit Area



Down to Bare Frame- Cables Out!

The last cable-wiring for the “chicken switch”



Installing Current-Limiting Resistors

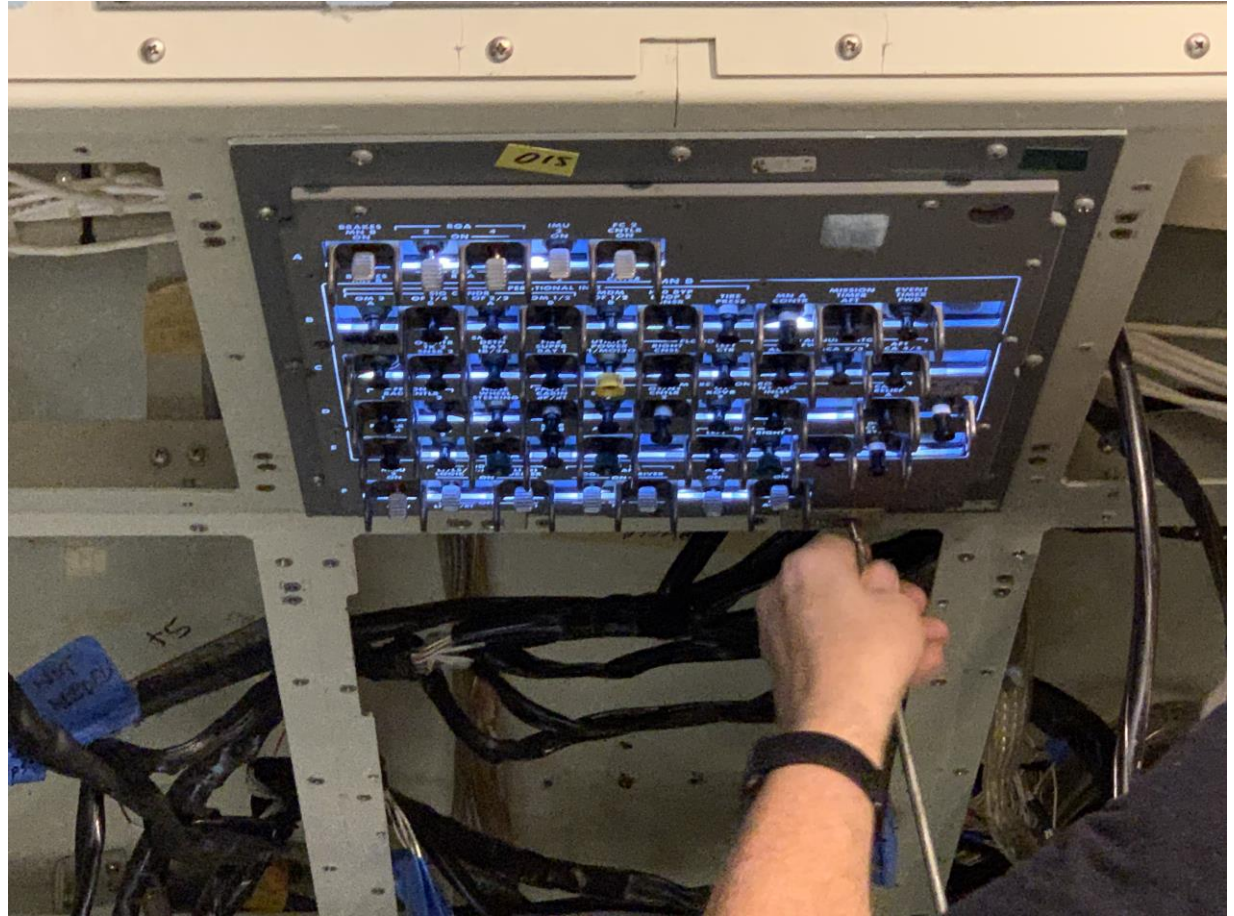
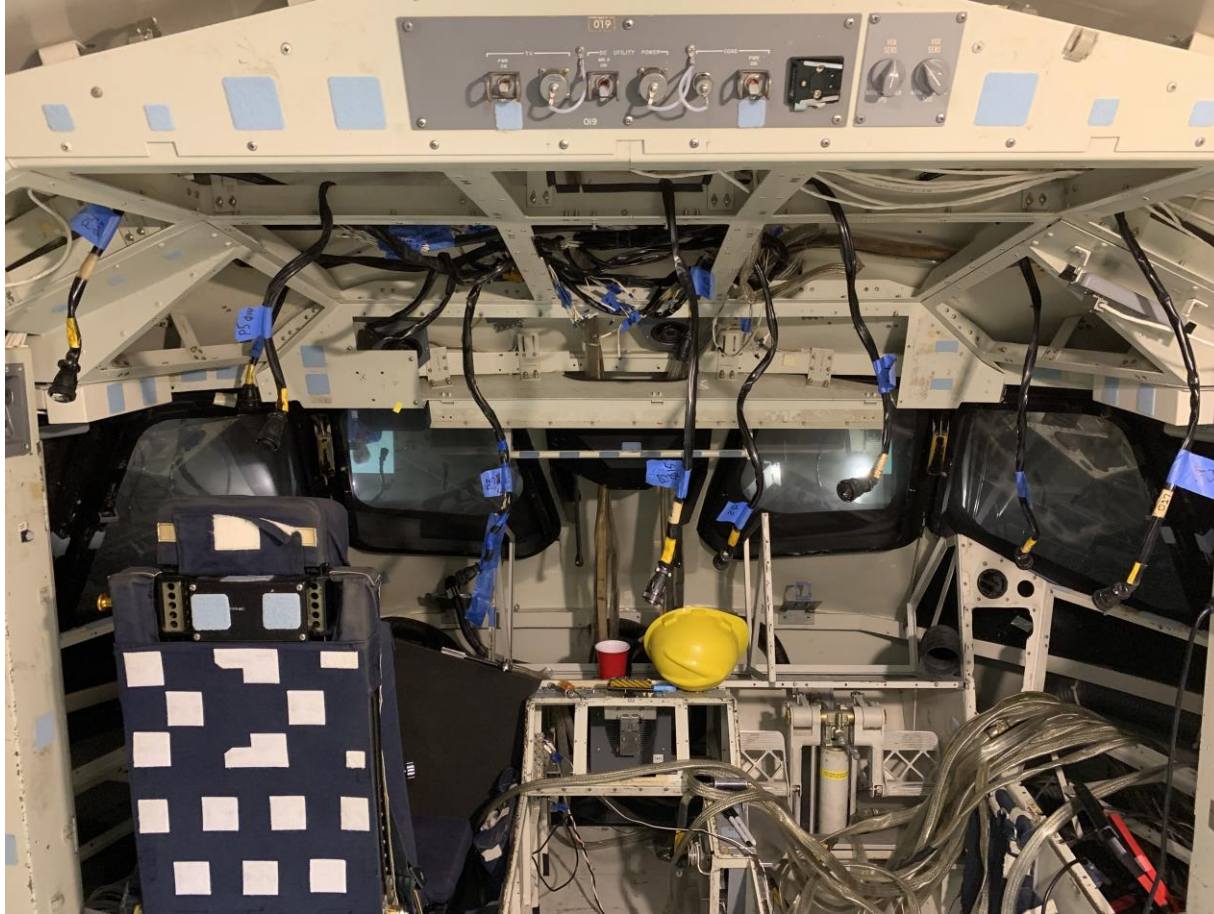


Structural Work & New Wheels

(Thank you Jacobs!)



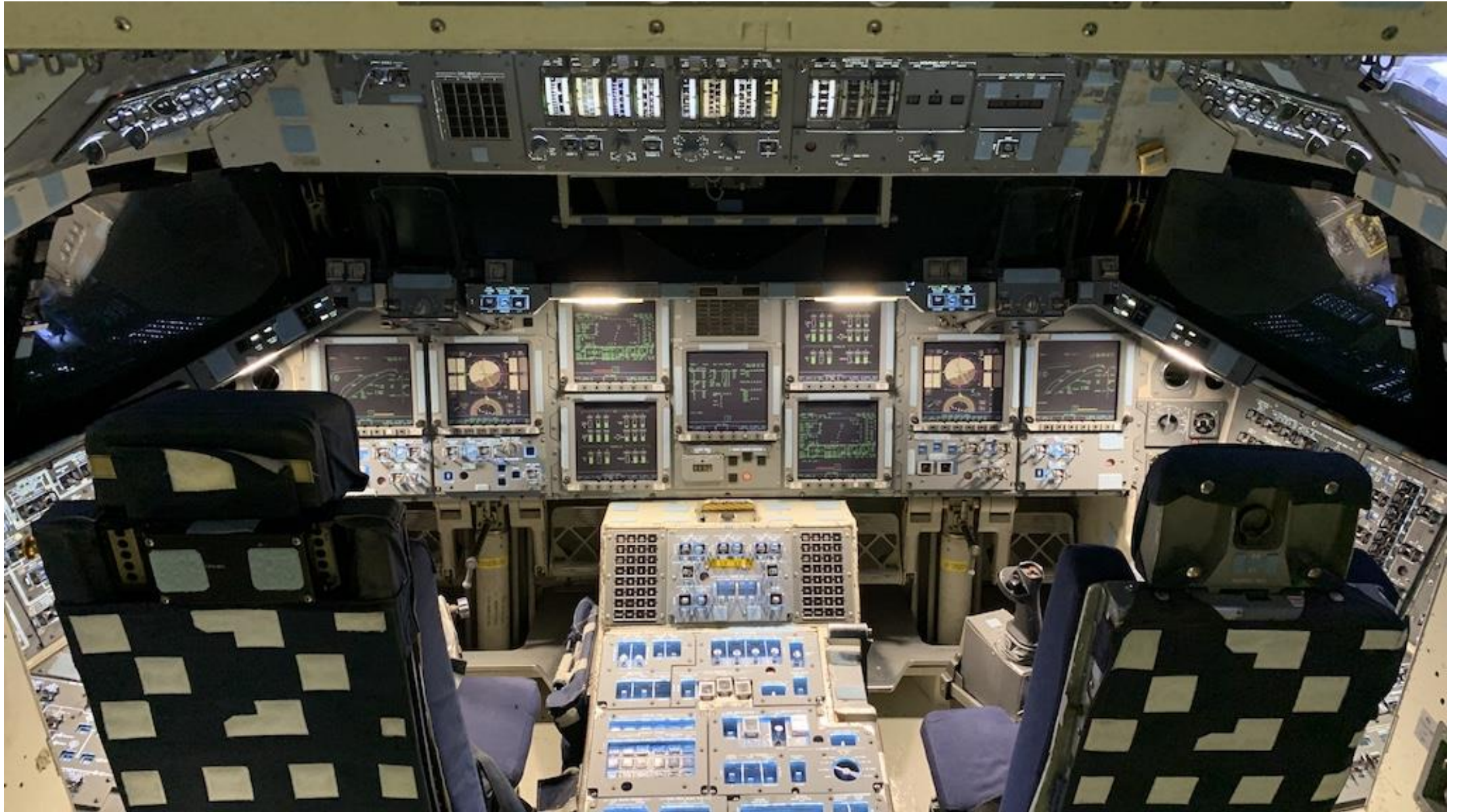
Cables for Panels/Installing Panels



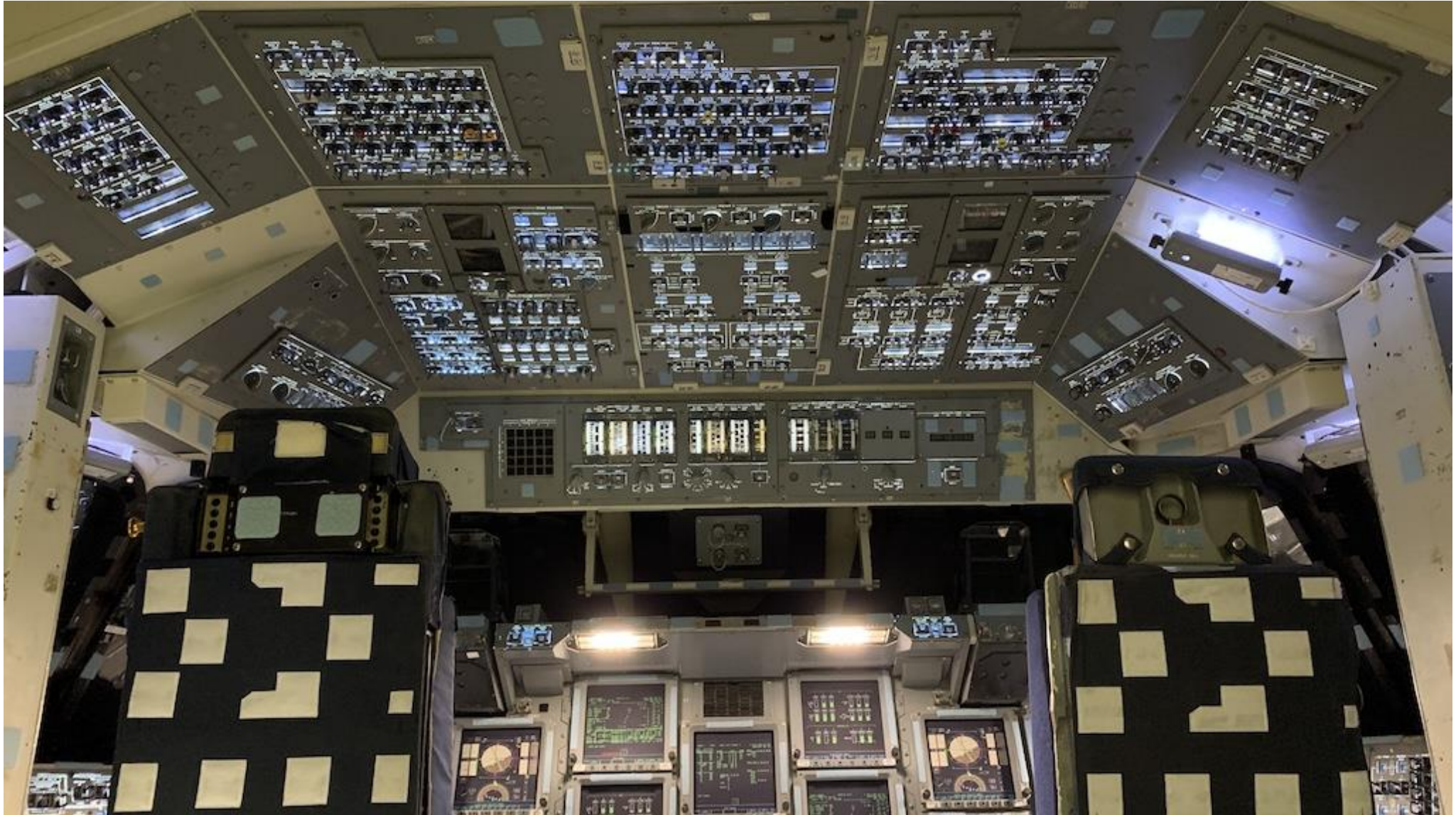
Touching Up Chipped Paint



All Panels Finally Installed! (as of 11/10)



Overhead Panels



The Volunteer Team



Left to Right-

Isaac Stoddard- GNC Engineer- Draper Labs
Wayne Sweeney- Simulator Engineering
David Dunn- Operations & Maintenance
Mike Sendelbach- Simulator Engineering
Gary Regier- Simulator Maintenance
David Rose- Flight Crew Instructor
Mike Barnard- Simulator Engineering
Carl Brainerd- Simulator Project Management
Bill Miller- Flight Crew Instructor

Not pictured-

Andy Foster- Flight Crew Instructor

Estimated 4000 hours invested so far.

Forward Work Plan

- Paint forward enclosure covers
- Reinstall forward enclosure covers
- Install visual projector amplifier boxes
- Paint cab exterior and cockpit floor
- Complete concept & design for audio/video display console
- Get or make videos for the video display
- Procure TV monitors for Crew Station and console
- Make access platform
- Get signage for the display
- Obtain and populate the display case(s)
- Move it all to the museum and set it up



View a Sample of Training Session Video: STS-135, Last Space Shuttle Crew

- Entry and landing at Edwards AFB runway 04 (last 8 minutes)
- Note the full audio captured
 - ALL crew conversation
 - Air-to-ground comm with Mission Control
 - Vehicle audio
 - Aerodynamic noise
 - Tire screech at touchdown
 - Runway “rumble”
 - Caution & Warning system alert tones and sirens
 - Etc.
- A set of these videos will play continuously inside the cab, and also at the audio/video console
- On to the video.....







A photograph of the Space Shuttle Columbia being mated to the External Tank and Solid Rocket Boosters by the Shuttle Carrier Mechanism at night. The shuttle is white with black and blue markings. The carrier mechanism is a complex structure of metal and lights. The scene is illuminated by bright lights, creating a high-contrast image against the dark blue night sky. The shuttle is positioned vertically, and the carrier mechanism is attached to its side. The background shows the silhouettes of other structures and a clear night sky.

THANK YOU

Carl Brainerd

Team Lead, Motion Base Restoration

11/14/21